Multisatellite team

AIRS-based HDO/H_2O

Comparison of HDO/H_2O from AIRS with ORACLES: an update

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AIRS HDO

Outline

1. Terminology
2. Scientific Motivation
3. HDO Retrieval
4. HDO/H_2O Comparisons

1. Terminology

Stable isotope terminology

Isotopologues: molecules differing in isotopic composition, e.g., H_2O versus HDO. These have slightly different physical properties, including molecular weight (18 versus 19) and vapor pressure.

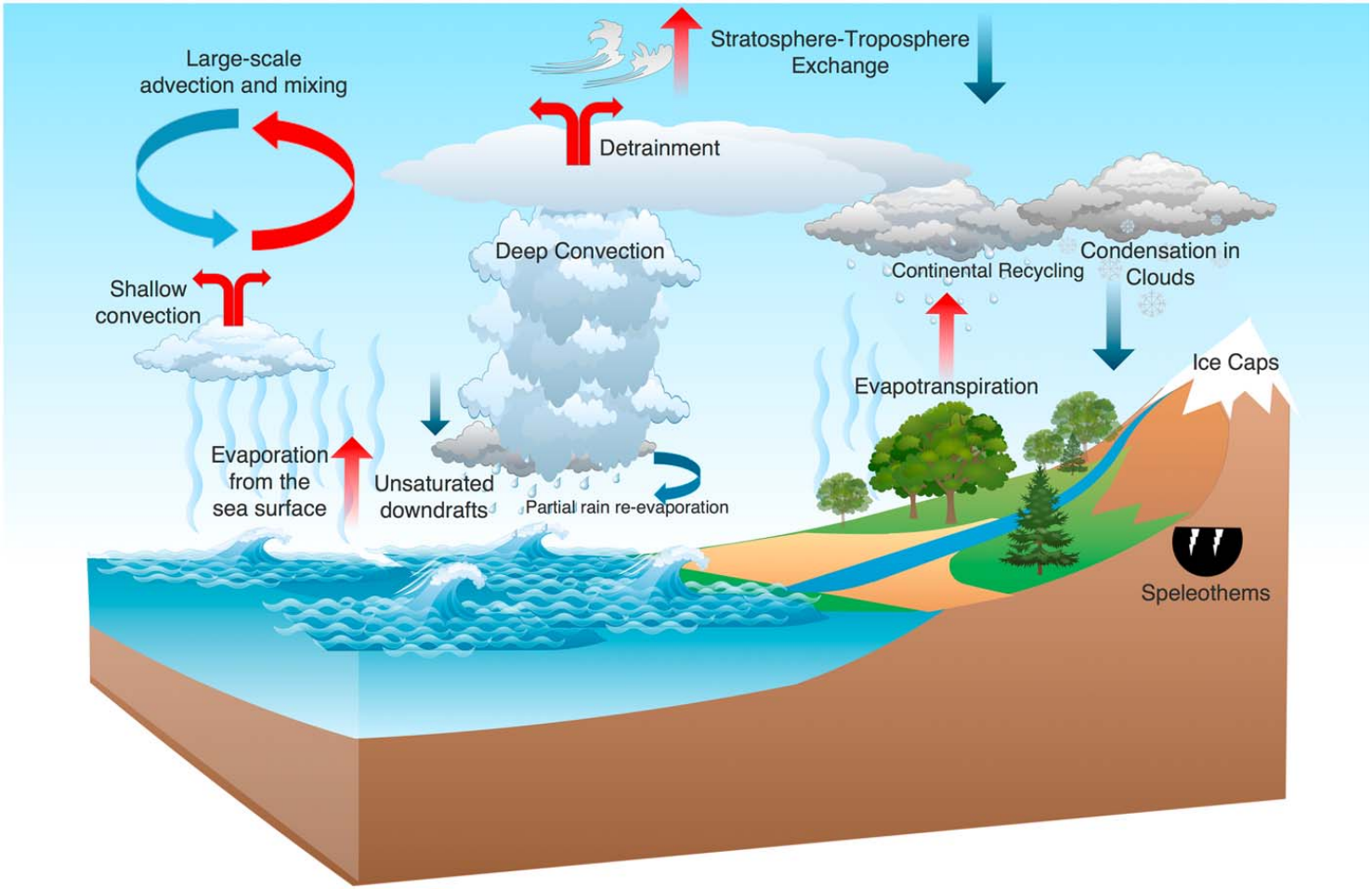
Water has several stable isotopologues, most abundant H_2O, HDO, $H_2{}^{18}O$.

Standard Mean Ocean Water (SMOW) has the isotopic ratio $(HDO/H_2O)_{SMOW} = 3.115 \times 10^{-4}$.

Delta notation: $\delta D_{sample} = [(HDO/H_2O)_{sample}/(HDO/H_2O)_{SMOW} - 1]*10^3$ (per mil or ‰).

2. Scientific Motivation

How water vapor isotopologues help evaluate hydrological processes (Galewsky et al., Rev Geo., 2015)



Red arrows describe ”enriching” process

Blue arrows describe “depleting” process

Lighter isotopologues of water preferentially evaporate. Heavier isotopologues (HDO) preferentially condense. Different moisture sources have different isotopic composition

Tropical Transpiration ~-65 to 0 ‰
Tropical Ocean Source ~-65 to -120 ‰
Tropical bare soil ~ -240 to -180 ‰

1) Quantifying rainfall evaporation in tropical monsoons (Worden et al., Nature 2007)
2) Partitioning transpiration and river run-off (Good et al., Science 2015)
3) Amazon transpiration initiates rainy season (Wright et al., PNAS 2017)

3. HDO Retrieval

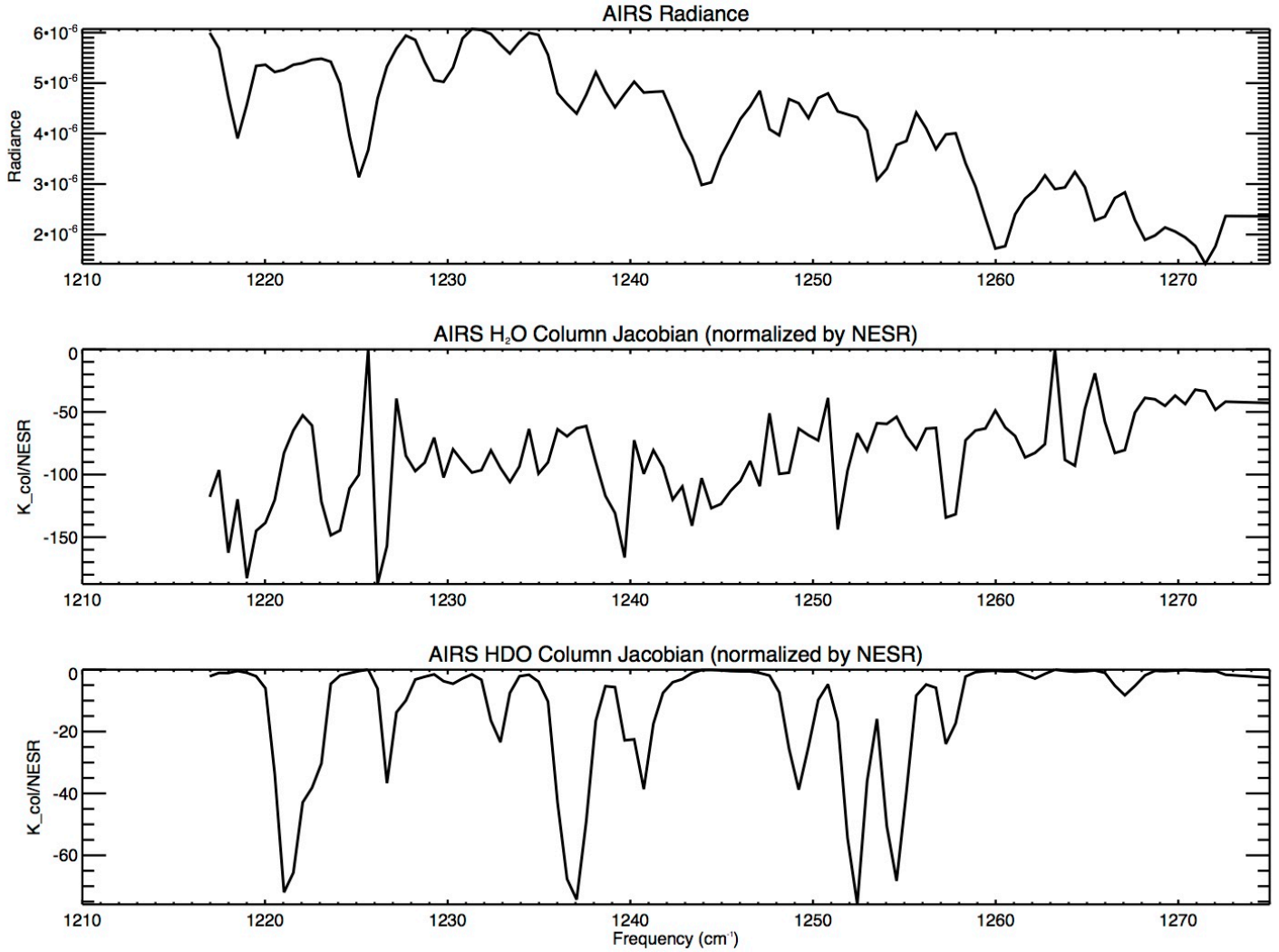
HDO Retrieval

- Optimal Estimation approach to retrieve Level 2 data products from AIRS single footprint IR geolocated and calibrated radiance data (Aumann et al., 2003).
- AIRS single footprint pixels have horizontal resolution of 13.5 km at nadir (see presentation by Bill Irion this afternoon).
- The Retrieval Framework is an optimal estimation retrieval algorithm (TES heritage) in which HDO is retrieved from AIRS.
- Retrieval paper for the HDO AIRS single-footprint retrieval will appear soon in AMT: Worden et al., in press*.
- AIRS and TES show a small bias for the HDO/H_2O ratio of 0.32 ± 2.3 per mil (Worden et al., in press).

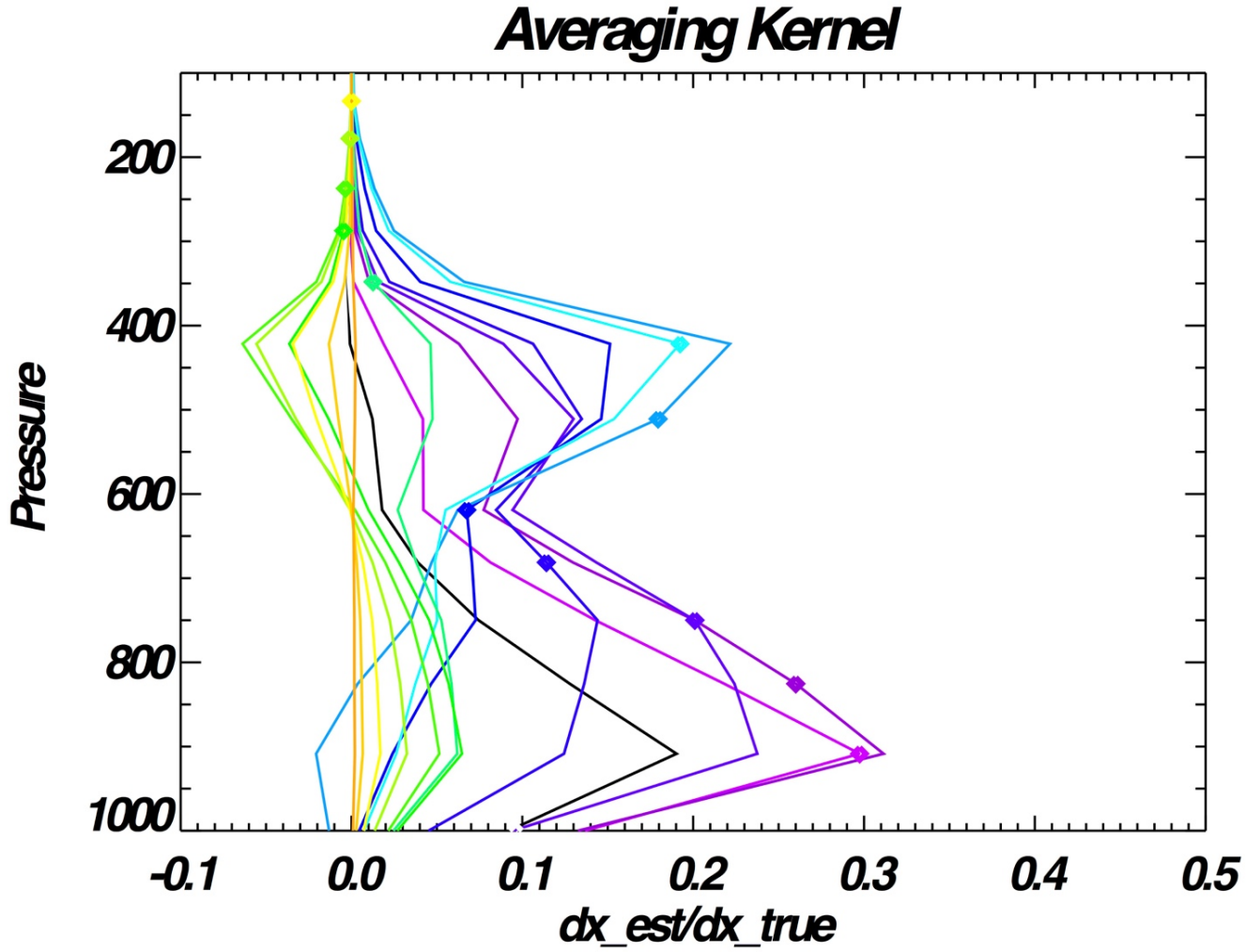
Worden, J. R., Kulawik, S. S., Fu, D., Payne, V. H., Lipton, A. E., Polonsky, I., He, Y., Cady-Pereira, K., Moncet, J.-L., Herman, R. L., Irion, F. W., and Bowman, K. W.: Characterization and Evaluation of AIRS-Based Estimates of the Deuterium Content of Water Vapor, Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2018-372, in review, 2018.

AIRS HDO/H_2O retrievals

AIRS radiances are utilized from ~650 to 1340 cm^{-1} (excluding the ozone band). Shown here are radiances and Jacobians near 1240 cm^{-1} where radiances are strongly sensitive to HDO:



The rows of the averaging kernel matrix for the HDO retrieval corresponding to the radiance shown on previous slide. Colors and symbols indicate the pressure levels corresponding to each row of the averaging kernel matrix.

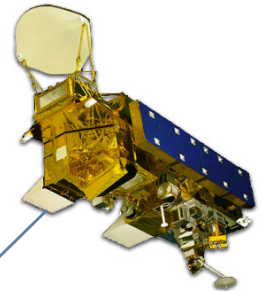


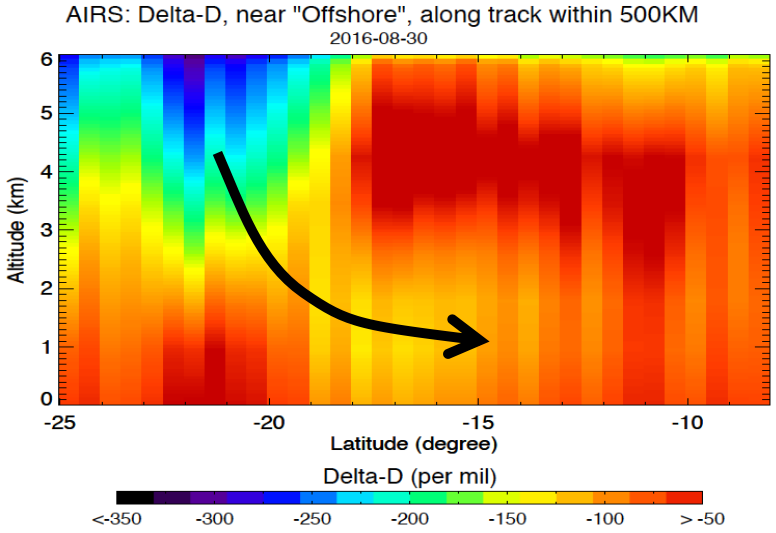
4. HDO/H_2O Comparisons

ORACLES (ObseRvations of Aerosols above CLouds and their intEractionS)

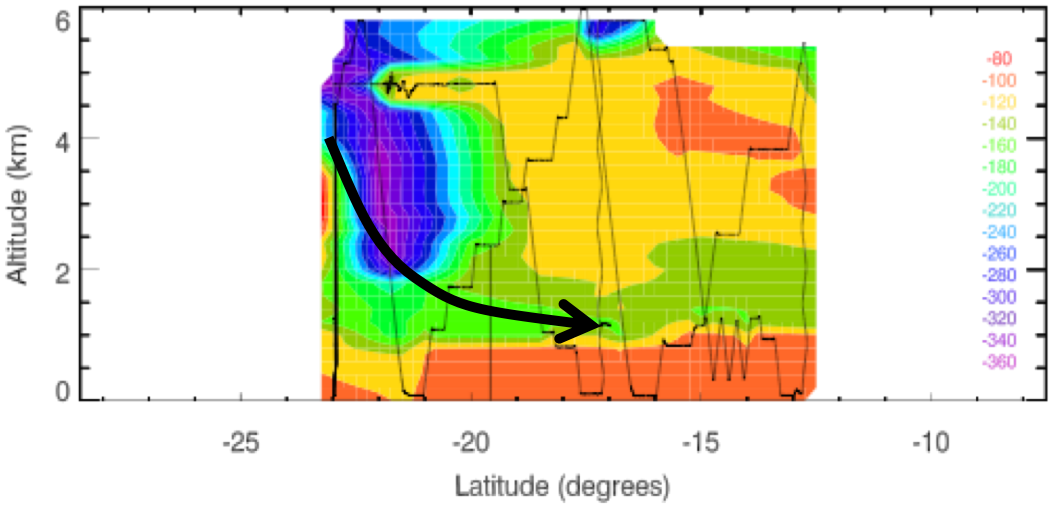
- A 5-year EVS-2 investigation to study key processes that determine the climate impacts of African biomass burning aerosols.
- ORACLES provides multi-year airborne observations (2016-2018) over the complete vertical column of the key parameters that drive aerosol-cloud interactions in the SE Atlantic, an area with some of the largest inter-model differences in aerosol forcing assessments on the planet.
- Science question relevant to AIRS: How do biomass burning aerosols affect cloud droplet size distributions, precipitation and the persistence of clouds over the SE Atlantic?
- Water Isotopologue measurements from the WISPER instrument on the P-3 aircraft (Noone's OSU group).

AIRS: HDO/H_2O



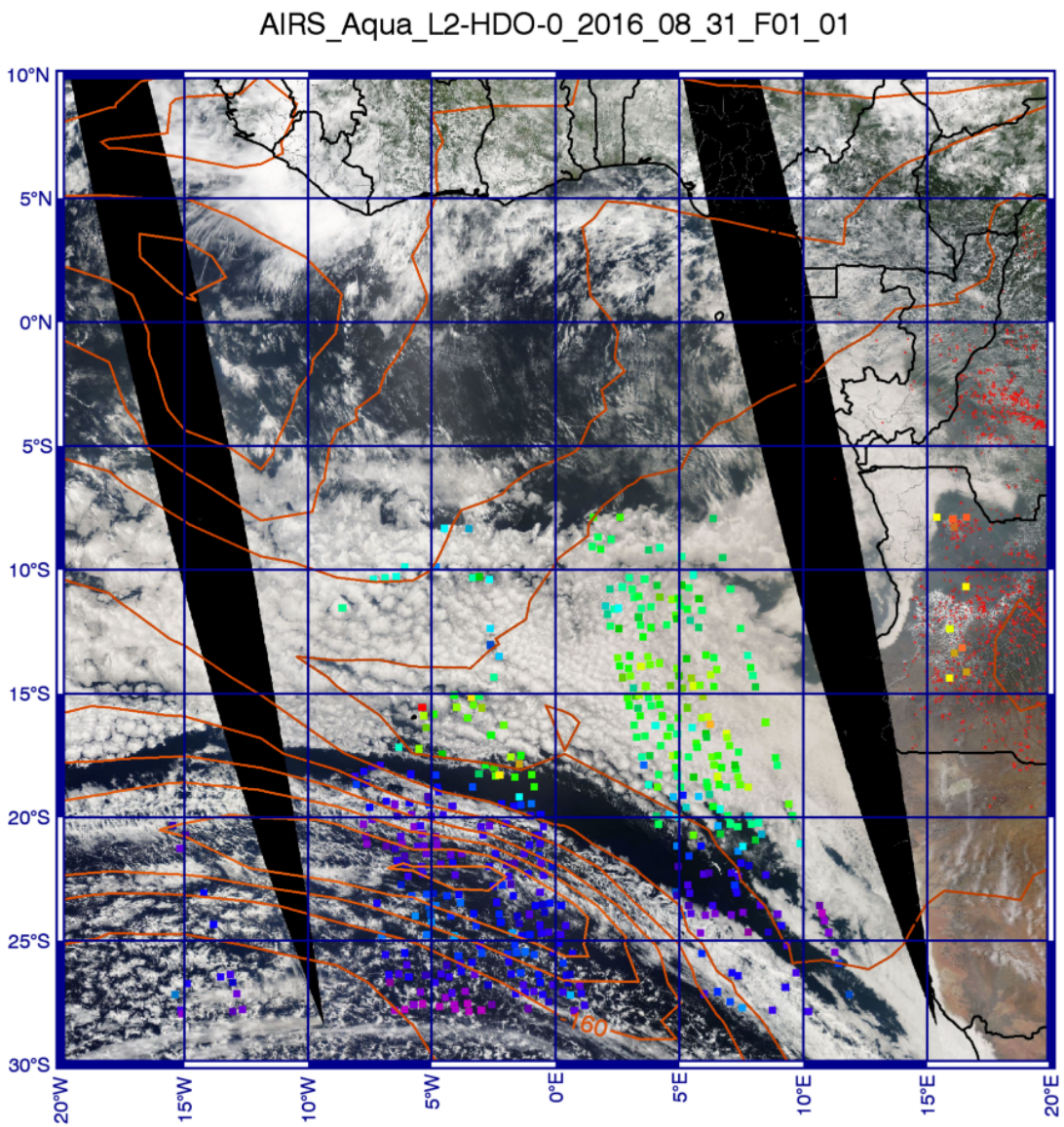


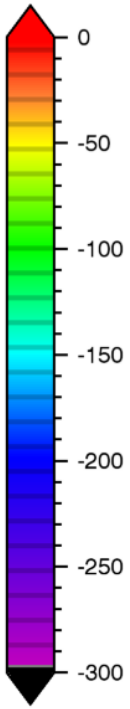
P-3: HDO/H_2O



Courtesy D. Noone (OSU)

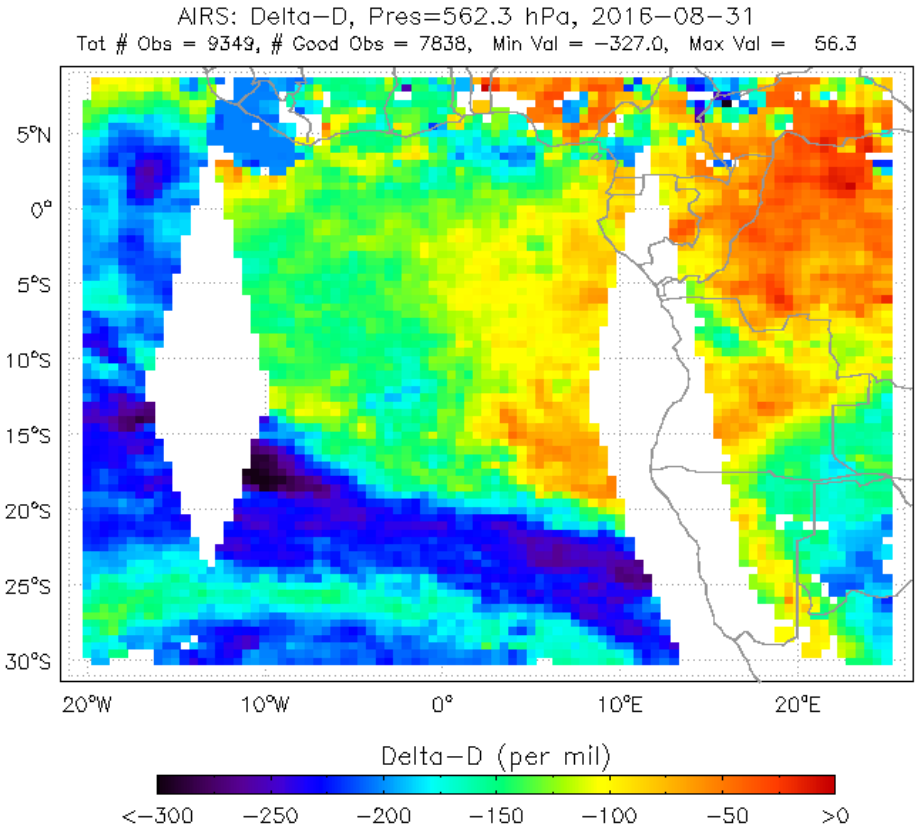
AIRS HDO/H_2O retrievals over Southeast Atlantic, 8-31-2016

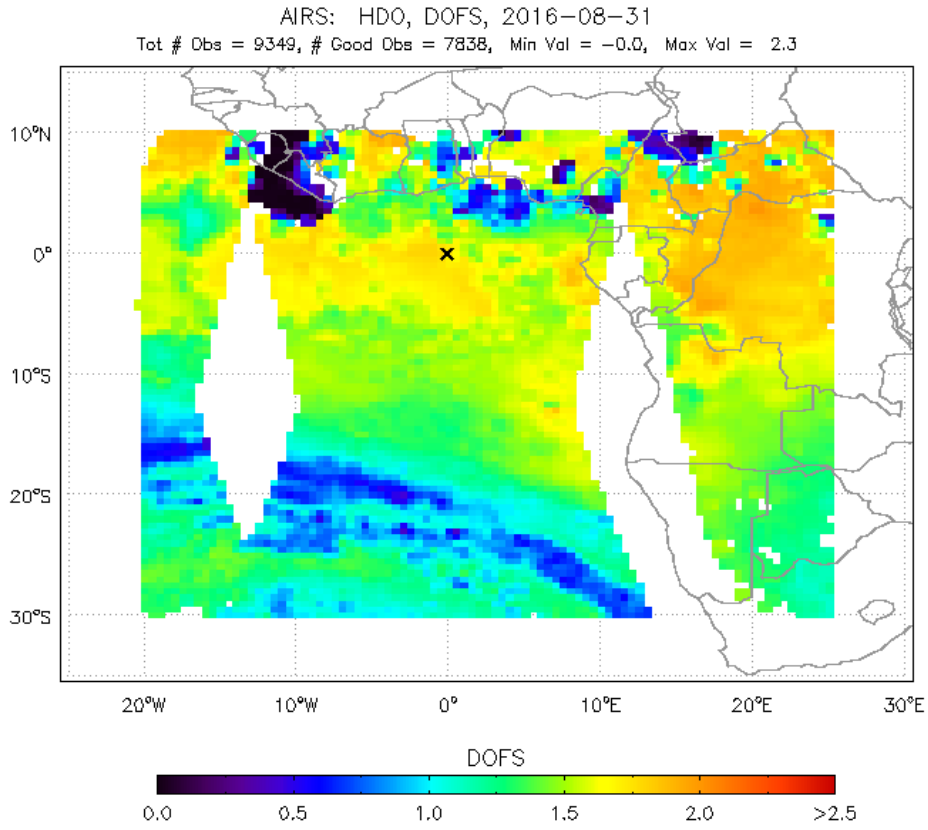




Color scale: mid-tropospheric AIRS delta-D.
Clouds: MODIS.

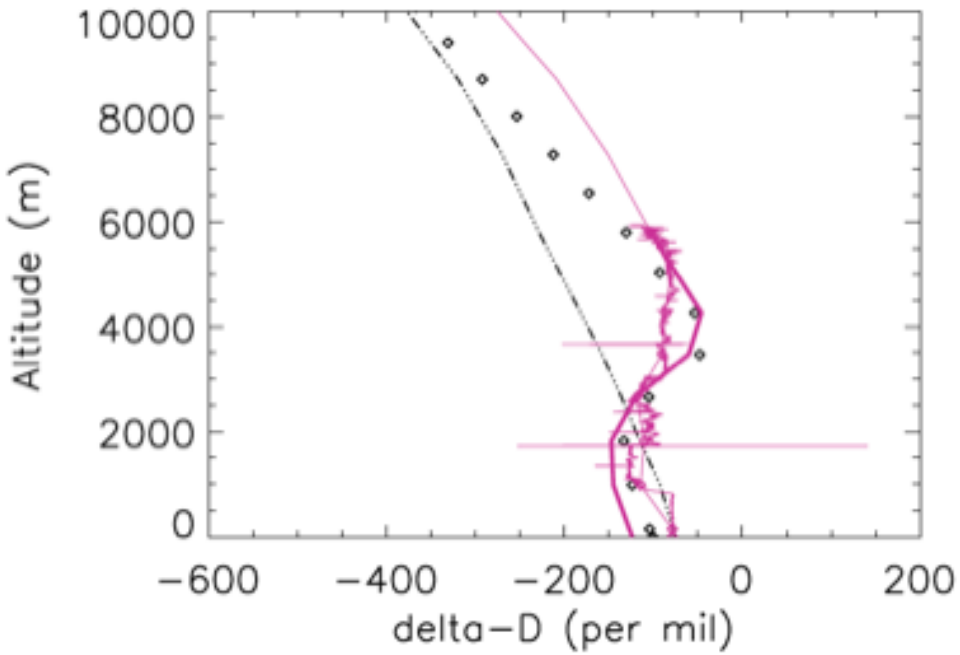
AIRS HDO/H_2O retrievals over Southeast Atlantic, 8-31-2016

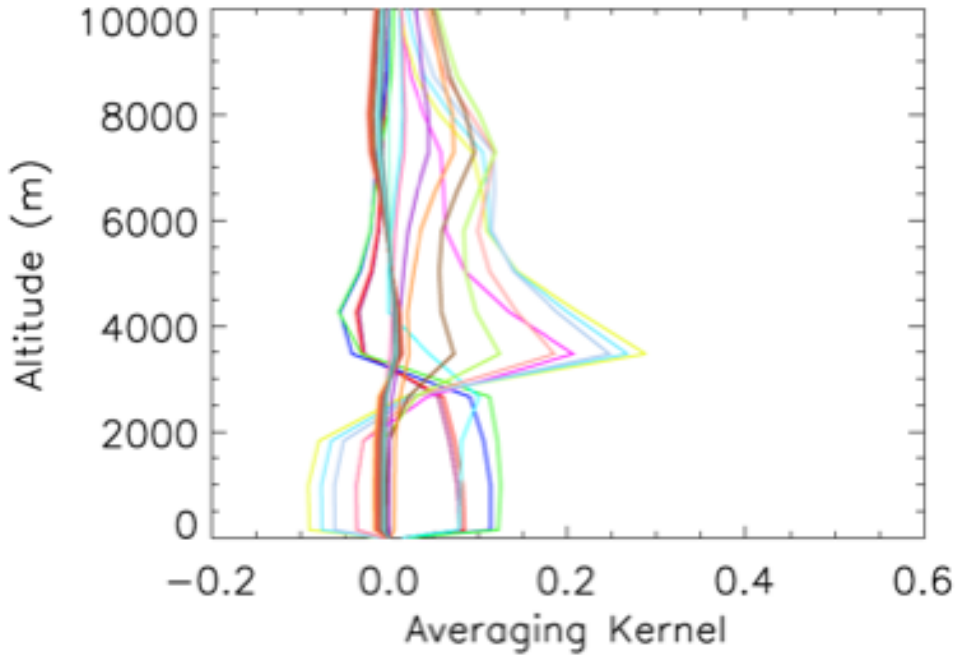




AIRS tropical HDO/H_2O estimates have ~1.5 Degrees of Freedom for Signal (DOFS).

Example Comparison of AIRS delta-D (blk diamonds) and **P-3 with AK** (thick red line)



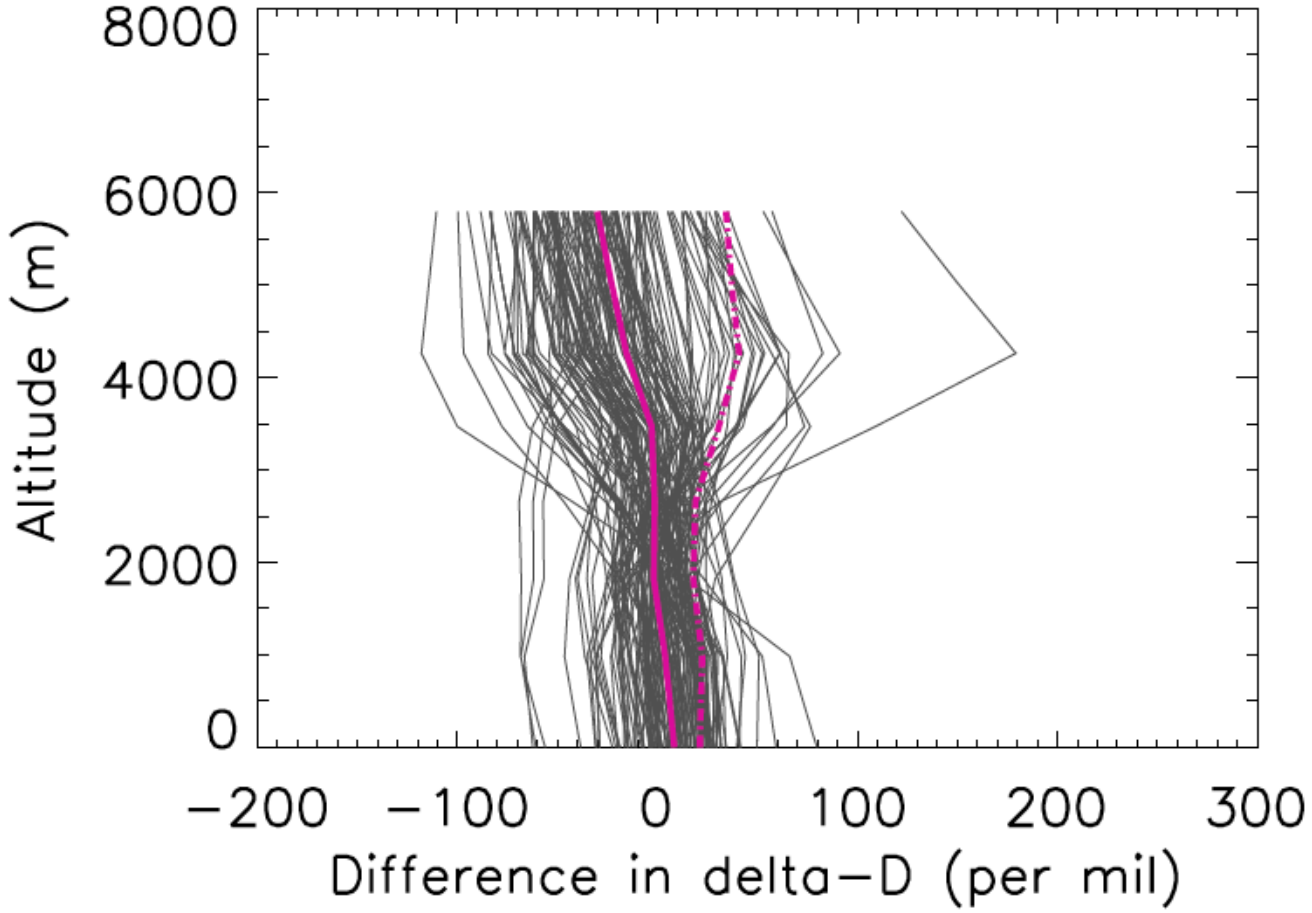


Location is 19.46 °S, 9.65 °E for coincident retrievals on 31 Aug 2016.

Statistics of AIRS minus P-3 delta-D

for 446 ORACLES spatially collocated profiles

(red solid line: mean, red dash: rms)



Summary:
AIRS HDO/H_2O retrievals are very well characterized ~1.5 DOFS.

AIRS bias relative to the aircraft is -8.0‰ in the lower troposphere and -4.6‰ in the middle troposphere.

AIRS RMS (in delta-d notation) is about 25 – 30 per mil.
This is consistent with aircraft RMS.

The small bias and consistent RMS suggests that the AIRS HDO/H2O retrieval provides well characterized measurements. This level of uncertainty is good enough to address science questions.

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AIRS

backup slides

Summary: importance of water isotopologues

Water isotopes provide useful information about the hydrological cycle, including:

- The overall intensity of the hydrological cycle.
- Transport and mixing processes in the atmosphere.
- Moisture sources (e.g. local vs distant, convection vs evapotranspiration).

Spaceborne instruments that measure isotopologues of water vapor, such as TES, IASI and AIRS, provide **regional** constraints on the hydrological cycle. The isotopic abundance in tropospheric water vapor is significantly different from the isotopic abundance in precipitation, so remote sensing provides a **unique** tool.

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